the receiver. When the second harmonics of these frequencies were greater than −136 dBm as received by the GPS antennas, the receiver could not lock on the GPS signal. Once the E-field strength was reduced to 0.1 V/m the receiver was able to lock on the GPS signal.

The above examples represent only a sample of possible and likely negative effects of higher levels of ambient electromagnetic fields in this frequency range on DOC Laboratory programs in the Boulder, Colorado, area. Other technical programs at NIST, as well as NOAA and ITS programs, may also be impacted.

9. SUMMARY AND CONCLUSION

In this report, we have analyzed the expected E-field strengths in the Boulder area from two proposed terrestrial DTV transmitter locations, the Eldorado Mountain site and the Squaw Mountain site. The Eldorado Mountain and Squaw Mountain sites were chosen in this study because these two possible sites bound the propagation environment that would occur at both the Table Mountain NRQZ and the DOC Laboratories. The Eldorado Mountain site affords substantial line-of-sight coverage over the Boulder area, and the Squaw Mountain site affords only indirect (diffractive) coverage over the same area. The other possible tower sites fall between these two types of propagation conditions. The proposed transmitter tower heights for the two sites were obtained from either the landowners or public documents.

In this analysis, measurements of the E-field strengths for a transmitter located at each of these sites were performed. These measured data were then compared to predicted E-field strengths obtained from the ITS ITM propagation model. The predicted field strengths from the two transmitter locations matched well with measured strengths from those locations at frequencies near both ends of the existing UHF television band. This indicates that the ITM predictions are reliable, and can be used with confidence in predicting the strengths that might be received at any given location in the area (with the exception of very deep shadowed regions) for any given transmitter and receiver heights.

The ITS ITM propagation model was then used to predict the E-field strengths in the Boulder area for the actual proposed transmitter antenna heights of two possible transmitter locations, Eldorado Mountain and Squaw Mountain. The E-field strengths were calculated based on 1.0 MW EIRP. Once the E-field strengths are obtained for 1.0 MW EIRP, the E-field strengths can be scaled to any desired transmitter power level. With these predictions, we were able to determine the E-field strengths at both the DOC Laboratories and at the Table Mountain NRQZ. The results presented here show that at the Table Mountain NRQZ, the predicted E-field strengths are about 0.3 V/m for a transmitter on Eldorado Mountain at 1.0 MW EIRP. This number exceeds the FCC's regulatory (47 CFR 73.1030) limit by about an order of magnitude. At that level, the research at the Table Mountain NRQZ will be compromised. The results also show that the E-field strengths at the DOC Laboratories for a transmitter located on Eldorado Mountain are about 1 V/m for 1.0 MW EIRP. These field strengths are high enough to possibly jeopardize the sensitive measurements done on a routine basis at the DOC

Laboratories, as discussed in Section 8. On the other hand, the results presented here show that at the Table Mountain NRQZ, the predicted E-field strengths are about 0.002 V/m for a transmitter located on Squaw Mountain for 1.0 MW EIRP. These field strengths are well within the FCC's Table Mountain NRQZ regulatory (47 CFR 73.1030) limit. Thus, the results presented here indicate that a transmitter could be located at Squaw Mountain without violating the FCC's regulatory limit or jeopardizing the research efforts at the Table Mountain NRQZ.

As discussed above, the measured and modeled data presented in this report are for an EIRP of 1 MW. As indicated in table 1, some of the DTV channels have maximum power allocations of 1.64 MW EIRP. The E-field strengths presented here can be transformed to a 1.64 MW EIRP by multiplying the data shown in all the figures by a factor of 1.3 (which would increase the E-field strengths by 30 %). This would result in even higher E-field strengths in the Boulder–Denver area than those presented here, and would cause even greater interference at both the DOC facilities due to a transmitter located on the Eldorado Mountain site. After scaling the results in this report to the current maximum EIRP levels (1.64 MW EIRP), the E-field strengths at both the Table Mountain NRQZ and DOC Laboratories can be determined for this maximum transmitter power level. The E-field strengths at the Table Mountain NRQZ would be about 0.4 V/m for a transmitter on Eldorado Mountain with 1.64 MW EIRP, and the E-field strengths at the DOC Laboratories would be about 1.3 V/m for 1.64 MW EIRP. In Reference [1], the FCC indicates that in the future, adjustments to the allocated power levels may be granted under some situations, in order to allow power levels higher than 1.64 MW. The FNPRM [5] indicated maximum ERP of 5 MW (or 8.2 MW EIRP). If these high power levels are granted, the result would be even higher E-field strengths in the Boulder–Denver area than those presented here.

In this report we also present data from a recent spectrum survey of the Table Mountain NRQZ. The results of this spectrum survey indicate that at the time of the survey (late 1998 and April 2001) the requirements of 47 CFR 73.1030 were being met by applicable signals at the Table Mountain NRQZ. The site therefore continues to be a useful and necessary location for present and future radio experiments. We also present results of a spectrum survey performed at the DOC Laboratories, illustrating a generally low level of ambient electromagnetic fields.

For DTV reception, the FCC specifies a minimum E-field strength of 41 dBμV/m (0.11 mV/m) for a receiver antenna at a height of 9.14 m (30 ft). Using the ITM prediction model, we also predicted the coverage areas where the FCC's minimum field strength for acceptable reception is met or exceeded. From the results shown here, it is seen that the two proposed transmitter locations (Eldorado Mountain and Squaw Mountain) have basically the same DTV coverage areas. However, the data in these results show that a transmitter on Squaw Mountain will not violate the FCC regulatory limits protecting the Table Mountain NRQZ.

The models and measurements discussed in this report can aid in determining whether the minimum field strength requirement of 41 dBμV/m can be achieved at various locations. However, another very important consideration for DTV (and any digital communication system, for that matter) is multipath effects. Multipath effects result in bit error rates (BER), or data error, in digital systems [33-39]. These effects can and do occur with DTV. The multipath issue is not isolated to the outdoor propagation environment. The multipath effects for an indoor propagation environment (i.e., a signal propagating to a TV antenna inside a house) can be equal or more critical [6, 40-44]. The indoor multipath issue is confronted in the following manner. In laying out the recommendations for DTV system designs (i.e., the Advanced Television Systems Committee (ATSC) standardization process), receiving antennas were assumed to be located on the outside of homes at an antenna height of 9.14 m (30 ft). However, this may not be possible for one reason or another (e.g., some communities have ordinances or covenants against external TV antennas). As a result, receiving antennas may be placed inside homes, either on top of TV sets or in attics. DTV signals propagating into homes will reflect off of surfaces and objects in the home, resulting in substantial multipath. This indoor multipath issue can have an adverse effect on the quality of service for DTV systems. More detailed studies are needed in order to determine whether the multipath environment from the two proposed sites is substantially different in order to assess the ultimate location of the antenna towers. Such a study can help in the assessments of the DTV receiver standards, in order to determine whether the indoor and outdoor multipath problem will affect the quality of service of terrestrial DTV systems and affect terrestrial DTV proliferation in the marketplace. This is important because of the issue of the encumbrances on the analog spectrum (i.e., channels 52 through 69), which are scheduled to be returned for other uses at the end of the DTV transition.

Furthermore, in a recent report [6], the ATSC Task Force has discussed the indoor DTV reception problem. This report includes reviews of the results of recent field tests of DTV reception in and around several major metropolitan areas in North and South America. For example, in the Washington, DC–Baltimore, Maryland, metroplex, it notes that DTV reception success fell from 75 % (on average) of all outdoor antenna sites with 9.14 m (30 ft) antennas to 32 % of all indoor antenna sites. (The indoor sites were preferentially chosen for adequate DTV electric field strengths outdoors, at the 9.14 m antenna height.) A considerable portion of the report is devoted to a discussion of potential improvements in DTV receiver and antenna technologies that would be likely to enhance DTV reception with indoor (and outdoor) antennas. Short of these improvements, the report lays out two possible options to improve indoor reception. The first option would be to lower the maximum data rate. The second option would be to increase the E-field strengths to make indoor reception more robust, by increasing DTV transmitters' ERPs. The ATSC report suggests that in order to overcome the indoor antenna problem, field strengths at the 9.14 m (30 ft) reference height may need to be increased substantially to 97 dBμV/m. This is an increase of 56 dB over the FCC's 41 dBμV/m, which is a factor of approximately 631 in field strength. This 56 dB increase can be obtained by either substantially reducing the coverage area of DTV reception or by increasing the power by 56 dB, clearly an unrealistic scenario. Obviously, if transmitter power levels are increased to compensate for the indoor problem, higher E-field strengths than those presented in this report could occur at both the DOC Laboratories and at the Table Mountain NRQZ, as well as at other areas throughout Boulder.

The studies in this report were carried out for two individual frequencies. In reality the DTV transmitter tower will have systems transmitting simultaneously over the entire band of frequencies shown in table 1. As discussed in this report, because of the way systems respond to a broad band of frequencies, a cumulative (integrated effect) amount of energy can couple into a system and adversely affect the sensitivity of a measurement, thereby potentially jeopardizing the quality of research performed at the DOC Laboratories. The data presented in this report illustrate that E-field strengths on the order of 1 V/m could be present at the DOC Laboratories. The studies presented in Section 8 illustrate only a few of the potential problems that may be experienced at the DOC laboratories.

While the results presented in this report are for omnidirectional or omni-azimuthal directional antenna patterns, they will remain relevant once the actual antenna patterns are known. For LOS propagation, the simple free-space calculation given in equation (2) can be used to determine the E-field strengths without the need to resort to the ITM prediction model. LOS propagation conditions occur for the Eldorado Mountain site for the Boulder area (including the DOC Laboratories and the Table Mountain NRQZ). Therefore, once the actual antenna patterns are known, the EIRP in any direction can be obtained, and equation (2) can be used to estimate the E-field strengths in LOS situations. An alternative approach is to simply scale the results in this report by the appropriate EIRP for an antenna at a given location. With this noted, the results in this report are valid for estimating the E-field strengths in the Boulder–Denver area. If additional results are needed for a given transmitting antenna pattern at a specific location, the ITM could be used for such analysis at a future date.